Analyzing nanoparticle shape impact on hybrid nanofluid flow over a Vertical Riga plate

Mohanaphriya US[a], Tanmoy Chakraborty[b,*]

*Corresponding Author

[a] Department of Mathematics, SRM Institute of Science and Technology,

Kattankulathur, Tamil Nadu, 603203, India. Email ID: mu0080@srmist.edu.in

[b] Department of Mathematics, SRM Institute of Science and Technology,

Kattankulathur, Tamil Nadu, 603203, India. Email ID: tanmoyc@srmist.edu.in

1. ABSTRACT

A Riga plate or electromagnetic actuator constructed by Gailitis and Lielausis [1] in 1961, features a flat surface embedded with electrodes and magnets arranged in an alternate manner. Riga plates have found applications in numerous fields, including aerospace engineering, maritime engineering, as well as in industrial processes where control of fluid flow is crucial. This study investigates the hybrid nanofluid flow over a vertical Riga plate, focusing on the impact of nanoparticle shape on flow dynamics and heat transfer characteristics. The hybrid nanofluid comprises engine oil as the base fluid, with copper and zirconium dioxide nanoparticles dispersed within it. The analysis considers different nanoparticle shapes, including spheres, bricks, cylinder and platelets, to understand how geometric variations influence the flow behaviour and thermal properties of the fluid. The effects of solar radiation and convective boundary condition is applied to model the thermal environment. The governing equations are solved numerically, and the results reveal the significant role of nanoparticle shape on the overall performance of the hybrid nanofluid. The findings demonstrate that the shape factor of nanoparticles critically affects the heat transfer rate, velocity distribution, and thermal boundary layer thickness. It is observed that, with an increase in the unsteadiness parameter, platelet-shaped nanoparticles exhibit higher velocity and temperature. The results indicate that the skin friction coefficient increases by 24.97% for the modified Hartmann number, but decreases by 5.19% with increasing unsteadiness parameter. Consequently, for the modified Hartmann number, Nusselt number increases across all nanoparticle's shapes by 2.03%, 1.94%, 1.80%, 1.71%. It is also found that the skin friction coefficient is higher for spherical shaped nanoparticles compared to platelet-shaped nanoparticle. It is noteworthy to mention that both the graphical illustration and computational results demonstrate that platelet-shaped nanoparticles provide the highest rate of heat transportation. They are followed by cylindrical, brick, and spherical-shaped nanoparticles. This indicates the superior thermal performance of platelet-shaped nanoparticles in enhancing convective heat transfer in the fluid. This study has applications in Maritime engineering to help improve the design of hull coatings with embedded nanofluids, to optimize the design of nanofluids for cooling systems in aircraft, potentially leading to more efficient thermal control and reduced energy consumption during flight.

Keywords: Vertical Riga plate, Hybrid nanofluid, particle shape factor, Convective boundary condition, Solar energy

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